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Introductory Chapter: Synchrotron Radiation-Basics and Concepts

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1. Introduction

When an electron traveling at nearly the speed of light in an orbit, emits a continuum of electromagnetic radiation tangential to the orbit, it gives you a synchrotron light which is the synchrotron radiation.

The main difference is that a cyclotron accelerates the particles in a spiral since the magnetic field is constant, whereas the synchrotron adjusts the magnetic field to keep the particles in a circular orbit. There are now more than 60 synchrotrons and free electron lasers (FELs) around the world dedicated to applications in physics, engineering, pharmacology, and new materials, to name but a few. As the electrons are deflected through the magnetic field created by the magnets, they give off electromagnetic radiation, so that at each bending magnet, a beam of synchrotron light is produced. SR—synchrotron radiation—can be used in a variety of spectroscopy techniques, namely, XAFS, soft X-ray, imaging, X-ray lithography, dispersive EXAFS, scanning EXAFS, EDXRD, XRF, protein crystallography, and X-ray beam diagnostic visible beam diagnostic to name a few.

1.1 Synchrotron radiation can give us a versatile field of X-ray spectroscopy which is the X-ray absorption spectroscopy (XAS)

X-ray interacts with all electrons in matter when its energy exceeds the binding energy of the electron. X-ray excites or ionizes the electron to a previously unoccupied electronic state (bound, quasi bound, or continuum). The study of this process is **XAS**.

Since the binding energy of core electrons is **element specific**, XAS is element and core level specific (e.g., Si K-edge at 1840 eV is the 1s electronic excitation threshold of silicon).

X-ray Absorption spectroscopy is often referred to as follows:

NEXAFS for low Z elements (C, N, O, F, etc. K-edge, Si, P, S, L-edges) or
XAFS (XANES and EXAFS) for intermediate Z and high Z elements.

As core electron is excited with $h\nu$ greater than or equal to the threshold (E_0), it is excited to a final state defined by the **chemical environment**, which modulates the absorption coefficient relative to that of a free atom. This **modulation** is known the **XAFS (Figure 1)**,

- XAFS contains all the information about the local structure and bonding of the absorbing atom
- XAFS study requires a **tunable X-ray source** which is the synchrotron radiation

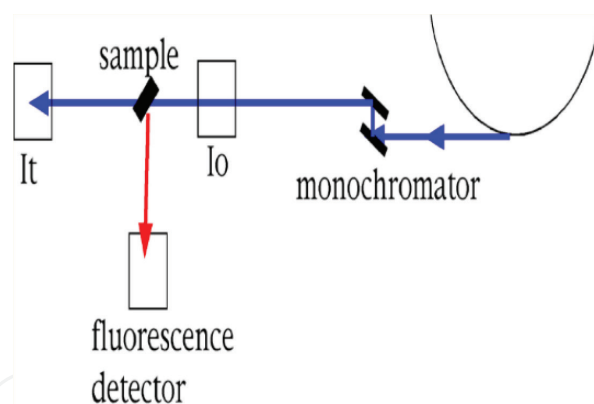


Figure 1.
XAS instrumentation.

NEXAFS (near edge X-ray absorption fine structures) describes the absorption features in the vicinity of an absorption edge up to ~50 eV above the edge (for low Z elements for historical reasons). It is exactly the same as **XANES** (X-ray absorption near edge structures), which is often used together with **EXAFS** (extended X-ray absorption fine structures) to describe the modulation of the absorption coefficient of an element in a chemical environment from below the edge to ~50 eV above (XANES), then to as much as 1000 eV above the threshold (EXAFS). **NEXAFS** and **XANES** are often used interchangeably. **XAFS** and **XAS** are also often used interchangeably.

Molecular spectra in absorption can be measured very efficiently using SR, and a survey of molecular cross-sections in the XUV of importance for Earth's atmospheric processes is at present being conducted. The energy of the electrons ejected by the photons can be measured with high accuracy. The binding energy of electrons in atoms is thus measured directly. The technique is generally called photoelectron spectroscopy (PES). The code symbols XPS, UPS, and ESCA are used to differentiate applications:

XPS is PES with X-ray sources; UPS is PES with U.V. sources. ESCA means electron spectroscopy for chemical analysis.

I hope that this book on Synchrotron Radiation will elucidate the technique of synchrotron radiation in a very crisp and precise manner. It will definitely bring out not only the technological aspects but also its applications in a variety of fields.

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